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(54) **Integrated memory controller circuit for fiber optics transceiver**

(57) A controller (110) for controlling a transceiver having a laser transmitter and a photodiode receiver. The controller includes memory (120, 122, 128) for storing information related to the transceiver, and analog to digital conversion circuitry (127) for receiving a plurality of analog signals from the laser transmitter and photodiode receiver, converting the received analog signals into digital values, and storing the digital values in predefined locations within the memory. Comparison logic (131) compares one or more of these digital values with limit values, generates flag values based on the comparisons, and stores the flag values in predefined locations within the memory. Control circuitry (123-1, 123-2) in the controller controls the operation of the laser transmitter in accordance with one or more values stored in the memory. A serial interface (121) is provided to enable a host device to read from and write to locations within the memory. Excluding a small number of binary input and output signals, all control and monitoring functions of the transceiver are mapped to unique memory mapped locations within the controller. A plurality of the control functions and a plurality of the monitoring functions of the controller are exercised by a host computer by accessing corresponding memory mapped locations within the controller.

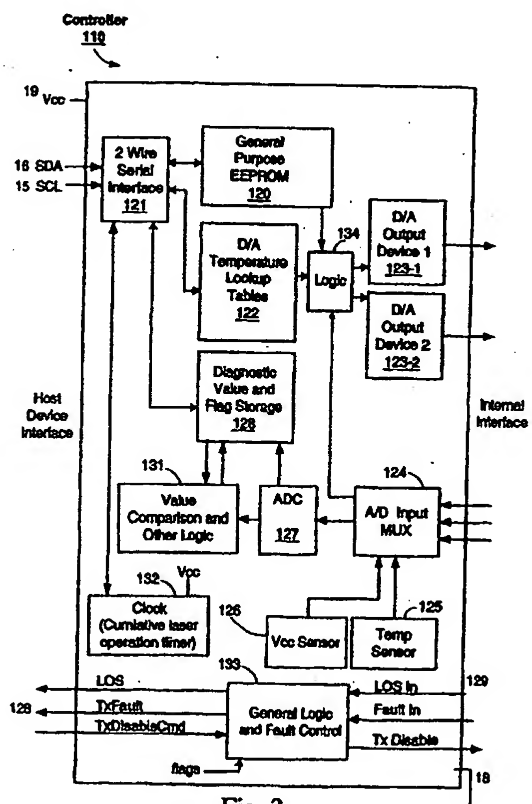

Fig. 3

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Description

[0001] The present invention relates generally to the field of fiber optic transceivers and particularly to circuits used within the transceivers to accomplish control, setup, monitoring, and identification operations.

BACKGROUND OF INVENTION

[0002] The two most basic electronic circuits within a fiber optic transceiver are the laser driver circuit, which accepts high speed digital data and electrically drives an LED or laser diode to create equivalent optical pulses, and the receiver circuit which takes relatively small signals from an optical detector and amplifies and limits them to create a uniform amplitude digital electronic output. In addition to, and sometimes in conjunction with these basic functions, there are a number of other tasks that must be handled by the transceiver circuitry as well as a number of tasks that may optionally be handled by the transceiver circuit to improve its functionality. These tasks include, but are not necessarily limited to, the following:

- Setup functions. These generally relate to the required adjustments made on a part-to-part basis in the factory to allow for variations in component characteristics such as laser diode threshold current.
- Identification. This refers to general purpose memory, typically EEPROM (electrically erasable and programmable read only memory) or other nonvolatile memory. The memory is preferably accessible using a serial communication standard, that is used to store various information identifying the transceiver type, capability, serial number, and compatibility with various standards. While not standard, it would be desirable to further store in this memory additional information, such as sub-component revisions and factory test data.
- Eye safety and general fault detection. These functions are used to identify abnormal and potentially unsafe operating parameters and to report these to the user and/or perform laser shutdown, as appropriate.

[0003] In addition, it would be desirable in many transceivers for the control circuitry to perform some or all of the following additional functions:

- Temperature compensation functions. For example, compensating for known temperature variations in key laser characteristics such as slope efficiency.
- Monitoring functions. Monitoring various parameters related to the transceiver operating characteristics and environment. Examples of parameters that it would be desirable to monitor include laser bias current, laser output power, received power level, supply voltage and temperature. Ideally, these parameters should be monitored and reported to, or made available to, a host device and thus to the user of the transceiver.
- Power on time. It would be desirable for the transceiver's control circuitry to keep track of the total number of hours the transceiver has been in the power on state, and to report or make this time value available to a host device.
- Margining. "Margining" is a mechanism that allows the end user to test the transceiver's performance at a known deviation from ideal operating conditions, generally by scaling the control signals used to drive the transceiver's active components.
- Other digital signals. It would be desirable to enable a host device to be able to configure the transceiver so as to make it compatible with various requirements for the polarity and output types of digital inputs and outputs. For instance, digital inputs are used for transmitter disable and rate selection functions while outputs are used to indicate transmitter fault and loss of signal conditions. The configuration values would determine the polarity of one or more of the binary input and output signals. In some transceivers it would be desirable to use the configuration values to specify the scale of one or more of the digital input or output values, for instance by specifying a scaling factor to be used in conjunction with the digital input or output value.

[0004] Few if any of these additional functions are implemented in most transceivers, in part because of the cost of doing so. Some of these functions have been implemented using discrete circuitry, for example using a general purpose EEPROM for identification purposes, by inclusion of some functions within the laser driver or receiver circuitry (for example some degree of temperature compensation in a laser driver circuit) or with the use of a commercial microcontroller integrated circuit. However, to date there have not been any transceivers that provide a uniform device architecture that will support all of these functions, as well as additional functions not listed here, in a cost effective manner.

[0005] It is the purpose of the present invention to provide a general and flexible integrated circuit that accomplishes all (or any subset) of the above functionality using a straightforward memory mapped architecture and a simple serial communication mechanism.

[0006] Fig. 1 shows a schematic representation of the essential features of a typical prior-art fiber optic transceiver.

The main circuit 1 contains at a minimum transmit and receiver circuit paths and power 19 and ground connections 18. The receiver circuit typically consists of a Receiver Optical Subassembly (ROSA) 2 which contains a mechanical fiber receptacle as well as a photodiode and pre-amplifier (preamp) circuit. The ROSA is in turn connected to a post-amplifier (postamp) integrated circuit 4, the function of which is to generate a fixed output swing digital signal which is connected to outside circuitry via the RX+ and RX- pins 17. The postamp circuit also often provides a digital output signal known as Signal Detect or Loss of Signal indicating the presence or absence of suitably strong optical input. The Signal Detect output is provided as an output on pin 18. The transmit circuit will typically consist of a Transmitter Optical Subassembly (TOSA), 3 and a laser driver integrated circuit 5. The TOSA contains a mechanical fiber receptacle as well as a laser diode or LED. The laser driver circuit will typically provide AC drive and DC bias current to the laser. The signal inputs for the AC driver are obtained from the TX+ and TX- pins 12. Typically, the laser driver circuitry will require individual factory setup of certain parameters such as the bias current (or output power) level and AC modulation drive to the laser. Typically this is accomplished by adjusting variable resistors or placing factory selected resistors7, 9 (i.e., having factory selected resistance values). Additionally, temperature compensation of the bias current and modulation is often required. This function can be integrated in the laser driver integrated circuit or accomplished through the use of external temperature sensitive elements such as thermistors 6, 8.

[0007] In addition to the most basic functions described above, some transceiver platform standards involve additional functionality. Examples of this are the TX disable 13 and TX fault 14 pins described in the GBIC standard. In the GBIC standard, the TX disable pin allows the transmitter to be shut off by the host device, while the TX fault pin is an indicator to the host device of some fault condition existing in the laser or associated laser driver circuit. In addition to this basic description, the GBIC standard includes a series of timing diagrams describing how these controls function and interact with each other to implement reset operations and other actions. Most of this functionality is aimed at preventing non-eyesafe emission levels when a fault conditions exists in the laser circuit. These functions may be integrated into the laser driver circuit itself or in an optional additional integrated circuit 11. Finally, the GBIC standard also requires the EEPROM 10 to store standardized serial ID information that can be read out via a serial interface (defined as using the serial interface of the ATMEL AT24C01A family of EEPROM products) consisting of a clock 15 and data 16 line.

[0008] As an alternative to mechanical fiber receptacles, some prior art transceivers use fiber optic pigtails which are standard, male fiber optic connectors.

[0009] Similar principles clearly apply to fiber optic transmitters or receivers that only implement half of the full transceiver functions.

SUMMARY OF THE INVENTION

[0010] The present invention is preferably implemented as a single-chip integrated circuit, sometimes called a controller, for controlling a transceiver having a laser transmitter and a photodiode receiver. The controller includes memory for storing information related to the transceiver, and analog to digital conversion circuitry for receiving a plurality of analog signals from the laser transmitter and photodiode receiver, converting the received analog signals into digital values, and storing the digital values in predefined locations within the memory. Comparison logic compares one or more of these digital values with limit values, generates flag values based on the comparisons, and stores the flag values in predefined locations within the memory. Control circuitry in the controller controls the operation of the laser transmitter in accordance with one or more values stored in the memory. A serial interface is provided to enable a host device to read from and write to locations within the memory. A plurality of the control functions and a plurality of the monitoring functions of the controller are exercised by a host computer by accessing corresponding memory mapped locations within the controller.

[0011] In some embodiments the controller further includes a cumulative clock for generating a time value corresponding to cumulative operation time of the transceiver, wherein the generated time value is readable via the serial interface.

[0012] In some embodiments the controller further includes a power supply voltage sensor that generates a power level signal corresponding to a power supply voltage level of the transceiver. In these embodiments the analog to digital conversion circuitry is configured to convert the power level signal into a digital power level value and to store the digital power level value in a predefined power level location within the memory. Further, the comparison logic of the controller may optionally include logic for comparing the digital power level value with a power (i.e., voltage) level limit value, generating a flag value based on the comparison of the digital power level signal with the power level limit value, and storing a power level flag value in a predefined power level flag location within the memory. It is noted that the power supply voltage sensor measures the transceiver voltage supply level, which is distinct from the power level of the received optical signal.

[0013] In some embodiments the controller further includes a temperature sensor that generates a temperature signal corresponding to a temperature of the transceiver. In these embodiments the analog to digital conversion circuitry

is configured to convert the temperature signal into a digital temperature value and to store the digital temperature value in a predefined temperature location within the memory. Further, the comparison logic of the controller may optionally include logic for comparing the digital temperature value with a temperature limit value, generating a flag value based on the comparison of the digital temperature signal with the temperature limit value, and storing a temperature flag value in a predefined temperature flag location within the memory.

[0014] In some embodiments the controller further includes "margining" circuitry for adjusting one or more control signals generated by the control circuitry in accordance with an adjustment value stored in the memory.

[0015] According to a first aspect of the present invention, there is provided a single-chip integrated circuit for controlling an optoelectronic transceiver having a laser transmitter and a photodiode receiver, comprising memory, including one or more memory arrays for storing information related to the transceiver; analog to digital conversion circuitry for receiving a plurality of analog signals from the laser transmitter and photodiode receiver, converting the received analog signals into digital values, and storing the digital values in predefined locations within the memory; control circuitry configured to generate control signals to control operation of the laser transmitter in accordance with one or more values stored in the memory; an interface for reading from and writing to locations within the memory; and comparison logic for comparing the digital values with limit values, generating flag based on the limit values, and storing the flag values in predefined locations within the memory.

[0016] Advantageously, the single-chip integrated circuit further includes a cumulative clock for generating a time value corresponding to cumulative operation time of the transceiver, wherein the generated time value is readable via the interface.

[0017] More advantageously, the single-chip integrated circuit further includes a power supply voltage sensor coupled to the analog to digital conversion circuitry, the power supply voltage sensor generating a power level signal corresponding to a power supply voltage level of the transceiver, wherein the analog to digital conversion circuitry is configured to convert the power level signal into a digital power level value and to store the digital power level value in a predefined power level location within the memory.

[0018] Preferably the comparison logic of the signal-chip integrated circuit includes logic for comparing the digital power level value with a power level limit value, generating a power level flag value based on the comparison of the digital power level signal with the power level limit value, and storing the power level flag value in a predefined power level flag location within the memory.

[0019] Preferably, the single-chip integrated circuit further includes a temperature sensor coupled to the analog to digital conversion circuitry, the temperature sensor generating a temperature signal corresponding to a temperature of the transceiver, wherein the analog to digital conversion circuitry is configured to convert the temperature signal into a digital temperature value and to store the digital temperature value in a predefined temperature location within the memory.

[0020] More preferably, the comparison logic of the single-chip integrated circuit includes logic for comparing the digital temperature value with a temperature limit value, generating a temperature flag value based on the comparison of the digital temperature signal with the temperature limit value, and storing the temperature flag value in a predefined temperature flag location within the memory.

[0021] Advantageously, the single-chip integrated circuit further includes fault handling logic, coupled to the transceiver for receiving at least one fault signal from the transceiver, and coupled to the memory to receive at least one flag value stored in the memory, and coupled to a host interface to transmit a computed fault signal, the fault handling logic including computational logic for logically combining the at least one fault signal received from the transceiver and the at least one flag value received from the memory to generate the computed fault signal.

[0022] According to a second aspect of the present invention, there is provided a single-chip integrated circuit for controlling an optoelectronic device comprising memory, including one or more memory arrays for storing information related to the optoelectronic device; analog to digital conversion circuitry for receiving a plurality of analog signals from the optoelectronic device, the analog signals corresponding to operating conditions of the optoelectronic device, converting the received analog signals into digital values, and storing the digital values in predefined locations within the memory; and a memory interface for reading from and writing to locations within the memory in accordance with commands received from a host device.

[0023] According to a third aspect of the present invention, there is provided a single-chip integrated circuit for controlling an optoelectronic transceiver having a laser transmitter and a photodiode receiver, comprising analog to digital conversion circuitry for receiving a plurality of analog signals from the laser transmitter and photodiode receiver, converting the received analog signals into digital values, and storing the digital values in predefined memory mapped locations within the integrated circuit; comparison logic for comparing the digital values with limit values, generating flag values based on the limit values, and storing the flag values in predefined memory mapped locations within the integrated circuit; control circuitry configured to generate control signals to control operation of the laser transmitter in accordance with one or more values stored in the integrated circuit; and a memory mapped interface for reading from and writing to locations within the integrated circuit and for accessing memory mapped locations within the integrated

circuit for controlling operation of the control circuitry.

[0024] According to a fourth aspect of the present invention there is provided a method of controlling an optoelectronic transceiver having a laser transmitter and a photodiode receiver comprising: in accordance with instructions received from a host device, reading from and writing to locations within a memory; and receiving a plurality of analog signals from the laser transmitter and photodiode receiver, converting the received analog signals into digital values, and storing the digital values in predefined locations within the memory; comparing the digital values with limit values, generating flag values based on the limit values, and storing the flag values in predefined locations within the memory; generating control signals to control operation of the laser transmitter in accordance with one or more values stored in the memory.

[0025] Preferably the method of controlling an optoelectronic transceiver having a laser transmitter and a photodiode receiver further includes generating a time value corresponding to cumulative operation time of the transceiver, wherein the generated time value is readable by the host device via the memory interface.

[0026] Advantageously, the method of controlling an optoelectronic transceiver having a laser transmitter and a photodiode receiver further includes converting an analog power supply voltage level signal, corresponding to a voltage level of the transceiver, into a digital power level value and storing the digital power level value in a predefined power level location within the memory.

[0027] More advantageously, the method of controlling an optoelectronic transceiver having a laser transmitter and a photodiode receiver includes comparing the digital power level value with a power level limit value, generating a power level flag value based on the comparison of the digital power level signal with the power level limit value, and storing the power level flag value in a predefined power level flat location within the memory.

[0028] Advantageously, the method of controlling an optoelectronic transceiver having a laser transmitter and a photodiode receiver further includes generating a temperature signal corresponding to a temperature of the transceiver, converting the temperature signal into a digital temperature value and storing the digital temperature value in a predefined temperature location within the memory.

[0029] More advantageously, the method of controlling an optoelectronic transceiver having a laser transmitter and a photodiode receiver includes comparing the digital temperature value with a temperature limit value, generating a temperature flag value based on the comparison of the digital temperature signal with the temperature limit value, and storing the temperature flag value in a predefined temperature flag location within the memory.

[0030] Preferably, the method of controlling an optoelectronic transceiver having a laser transmitter and a photodiode receiver further includes receiving at least one fault signal from the transceiver, receiving at least one flag value stored in the memory, logically combining the at least one fault signal received from the transceiver and the at least one flag value received from the memory to generate a computed fault signal, and transmitting the computed fault signal to the host device.

[0031] According to a fifth aspect of the present invention there is provided a method of controlling an optoelectronic device comprising: in accordance with instructions received from a host device, reading from and writing to locations within a memory; and receiving a plurality of analog signals from the optoelectronic device, the analog signals corresponding to operating conditions of the optoelectronic device, converting the received analog signals into digital values, and storing the digital values in predefined locations within the memory; wherein the method is performed by a single-chip controller integrated circuit.

[0032] According to a sixth aspect of the present invention there is provided a method of controlling an optoelectronic transceiver having a laser transmitter and a photodiode receiver comprising: in accordance with instructions received from a host device, reading from and writing to memory mapped locations within a controller of the optoelectronic transceiver; receiving a plurality of analog signals from the laser transmitter and photodiode receiver, converting the received analog signals into digital values, and storing the digital values in predefined memory mapped locations within the controller; comparing the digital values with limit values, generating flag values based on the limit values, and storing the flag values in predefined memory mapped locations within the controller; generating control signals to control operation of the laser transmitter in accordance with one or more values stored in the predefined memory mapped locations within the controller; analog to digital conversion circuitry for receiving a plurality of analog signals from the laser transmitter and photodiode receiver, converting the received analog signals into digital values, and storing the digital values in predefined memory mapped locations within the controller.

[0033] Advantageously, the method of controlling an optoelectronic transceiver having a laser transmitter and a photodiode receiver further includes generating and storing in a register a time value corresponding to cumulative operation time of the transceiver, wherein the register in which the time value is accessed by the reading step as a memory mapped within the controller.

BRIEF DESCRIPTION OF THE DRAWINGS

[0034] Additional objects and features of the invention will be more readily apparent from the following detailed de-